PROGRESS OF LOWER HYBRID CURRENT DRIVE EXPERIMENT TOWARDS LONG-PULSE OPERATION ON EAST

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Lower hybrid current drive (LHCD) system operating at 4.6 GHz is the main tool for long-pulse operation on EAST. It is powered by 24 klystrons and each can run with an output power of 0.25 MW for 1000 s on a matched dummy load. The LH power is coupled into plasmas by a full active multijunction (FAM) launcher which is actively water-cooled. The progress and dominant limit in the high-power and long-pulse operation are summarized since it was built up in 2014. Before 2017, strong hot spots on the guard limiters and arcing events in front of the antenna were often observed when the LH power was larger than 2.0 MW [1], due to the low thermal transfer efficiency of the heat sink in the guard limiters. Thanks to the upgraded tungsten guard limiters (from the 2017 campaign) which can withstand a heat flux up to 12.9 MWm^{-2}[2], significant progress has been achieved in high-power long-pulse operation, as shown in figure 1. The system can operate in the power range of 2.5 – 2.8 MW with the pulse length ~ 10 s routinely. The maximum LH power coupled into plasmas reached 3.7 MW (corresponding to the power density ~ 22.6 MWm^{-2} and ~ 61% of the total nominal power 6 MW), but with many power trips due to the mismatch between the magnetic flux surface and the antenna shape. As a result, the averaged LH power (over the pulse length) was only 3.0 MW in figure 1. It is seen that the LH power injected into plasmas decreases significantly with the pulse duration increasing. Typical long-pulse achievements are: 102 s with 2.4 MW LH power in L-mode [3], 1056 s with 1.1 MW in I-mode [4], and the longest pulse length 1066 s with 0.92 MW in H-mode (achieved in 2025). For long-pulse (> 100 s) operation, the dominant power limitation is not from the LHCD system itself, but from other issues, such as plasma density and configuration control.

The anomalous loss of LHCD efficiency at high plasma density is the primary limit of steady-state long-pulse operation at physics [5]. To extend steady-state operational domain, improvement of the CD efficiency at high plasma density is investigated and summarized. Several methods have been confirmed to improve the CD efficiency on EAST experiments, such as lithium coating, using higher wave frequency and favourable $B_t \times \nabla B_t$ direction. In addition, it is found that high electron temperature at plasma centre by ECRH can reduce the LH power loss in the edge, which is beneficial to increase the CD efficiency further [6]. The experimental CD efficiency (η_{CD}) in quasi-steady-state H-mode plasmas is as high as ~ 1.1 (10^{19} A/W/m2) with the line-averaged density ($\bar{n}_e$) around 3.1 ($10^{19}m^{-3}$) (see figure 2). For the plasma density higher than 3.1 ($10^{19}m^{-3}$), the CD efficiency decreases slightly with density increasing due to the lower electron temperature. A CD efficiency of 0.9 (10^{19} A/W/m2) has been achieved with the density up to ~ 5.4 ($10^{19}m^{-3}$). The CD efficiency in H-mode plasmas is higher compared to the L-mode with similar line-averaged density. The main causes for the different efficiency between L- and H-modes are discussed. Finally, the future outlook is presented with a new LHCD system at 4.6 GHz with a passive active multijunction (PAM) launcher [7].

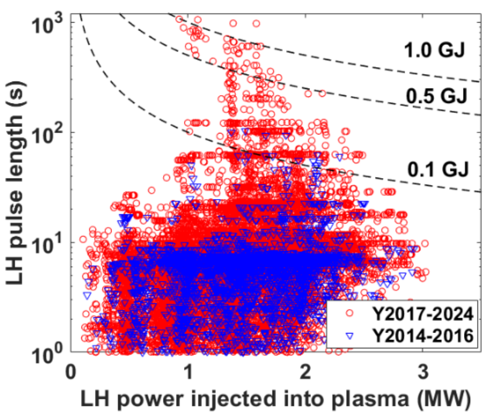

Figure 1. LH pulse length versus injected power on EAST (f = 4.6 GHz)

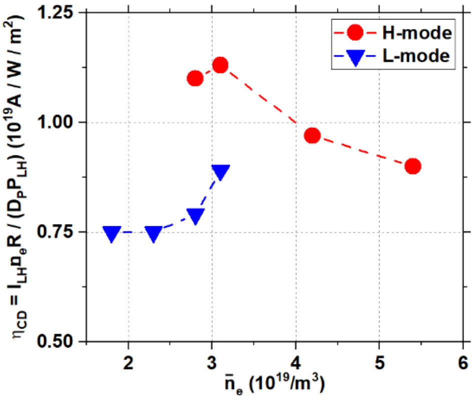

Figure 2. LHCD efficiency (η_{CD}) in L- (blue) and H-mode (red) plasmas as a function of electron density. D_p = 0.75 is the power spectrum directivity.

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